Lecture
Module 5: Hydrologic Processes

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Learning Objectives

Upon completion of this module, the participant will be able to:

1. Describe the hydrologic cycle in relation to landscape attributes.

2. Predict the path of water by infiltration, runoff, and evapotranspiration.

3. Describe fundamental stream processes such as sediment transport and deposition.

4. Describe landscape-level processes that affect hydrology and how they influence stream channel morphology.

5. Describe how issues related to hydrology (e.g., surface runoff, infiltration, acid deposition, streambank erosion, groundwater pollution) affect design of conservation practices.

K. Boyer

Lecture Outline

Water balance equation: runoff = precipitation + interception + evaporation + transpiration + /- storage

Precipitation
- Measurements
- Types
- Distribution

Interception

Evaporation and Transpiration

Infiltration and storage

Streamflow generation
- Types of streams
- Factors influencing flow
- Hortonian or overland flow
- WRENSS model

Discharge
- Hydrographs
- Stream gauging
- Weirs and flumes
- Flow duration curves

Water resources management
- Channel formation
- Sediment movement and deposition
- Watershed changes
- Riparian zones
- Watershed health

Exercises

A) Classroom Exercise. This assignment is the start of several exercises designed to familiarize the user with both on-line data and previously published references. The exercise will focus on one watershed of your choosing, using precipitation, streamflow, and soils data. It will be necessary to secure a copy of a local County Soil Survey Report for this exercise.

Objective*s*: to define a watershed using topographic maps; to use a soil survey to locate different soil groups as related to landscape and hydrologic position.

Methods: You will need to locate both a stream gauging station and a nearby weather station. Both real-time and historical streamflow data are available from the U.S. Geological Survey website http://water.usgs.gov/nwis/discharge. Web navigation directs you to historical streamflow data through ‘Surface Water.’

Locate a stream gauging station of interest in a watershed of 7th level or higher, that is a watershed less than 10,000 acres in area. Obtain the appropriate topographic maps to delineate the watershed boundary, which is all the land that will contribute to streamflow at your gauging station location. How does your estimate of area compare to the published area? Speculate on reasons for differences.

Overlay the soils map on the watershed map. These should both have a scale of 1:24000. Identify the different soil polygons as related to landscape position (see Soils). For each of the dominant soil polygons determine the hydrologic soils group (A,B,C, or D). What is the location of the D soils? Would these soils be appropriate locations for land management or land disturbing activities? Why?

Go to the web and download the historical streamflow for your station. Download at least five years of record. Download mean daily flows and plot the five years of daily flow over time. Remember that the water year begins October 1 and ends September 30. Describe the annual hydrology of your watershed.

B) Field Exercise. Visit the watershed you selected for the classroom exercise. Before you go, download the real time streamflow data. This site visit may be coordinated with the Soils Exercise.

Visit the gauging station. Locate the outside reference and read the stage. Estimate the streamflow (cross-sectional area X stream velocity). How does your estimate compare to the real time data? Speculate on what you can do to improve your estimate. Calculate the water yield in acre-feet per day given the daily streamflow. Is there evidence of a bankfull discharge? Look for high water marks delineated by organic debris in the channel and the streamside vegetation.

At the gauging station, evaluate the stream reach for 5-10 times the stream width. Look at the stream, hillslope vegetation, watershed position and surrounding land uses. Record your impressions. Measure the secondary axis (width) of several dozen particles of the bed material and estimate the degree of sorting or packing. Note stability (or lack of) based on large woody material, streamside/riparian vegetation, and channel shape (width/depth) or meandering. Does this stream reach represent a proper functioning condition? Why or why not?

Move up the watershed to another channel cross-section, or to a smaller sub-watershed. Repeat the observations as per the above paragraph. For the classroom exercise, you identified several soil polygons that were in hydrologic soils groups C or D. Locate these areas in the watershed, when near the stream.

Is there a relationship between stream particle size and stream velocity? Between land use activities or soils? What other relations can be considered: include riparian vegetation, fish habitat, terrestrial habitat, soils, or other resources or uses. Do the different stream reaches each represent a stable or proper functioning condition for all situations? If you had an unrestricted budget, what would you do to improve or increase the stream condition?

One of the take-home lessons here is to learn how to identify the hydrologic connectivity in a watershed and what we can do as managers to either maintain that connectivity or help to re-establish those watershed level linkages. The physical processes create the template for all biological processes.

Study Questions

1. Infiltration rates of precipitation depend on soil type, pore size and organic content of the soil. What role does vegetation play in infiltration and how should vegetative cover be managed to maximize infiltration and minimize overland flow of water?

2. What is the Proper Functioning Condition (PFC) Assessment?

3. Stream channel morphology in the absence of human land use is a function of geology, climate, and vegetation. Perturbations such as water diversions, livestock grazing in riparian areas, and channel straightening can result in downcutting or channel incision. What conservation practices can be implemented that will minimize degradation of stream channels on farms and ranches?

References and Selected Reading

Bras, R. L. 1989. Hydrology: An introduction to hydrologic sciences. Addison Wesley, Reading, MA.

Dissmeyer, G. (ed). 2000. Drinking water from forests and grasslands: a synthesis of the scientific literature. USDA Forest Service, Southern Research Station. Report SRS-39. 246pp.

Dunne, T. and L. B. Leopold. 1978. Water in environmental planning. W. H. Freeman. San Francisco. 818pp.

Lee, R. 1980. Forest hydrology. Columbia University Press.

Leopold, L. B., M. G. Wolman, and J. P. Miller. 1964. Fluvial processes in geomorphology. W. H. Freeman and Company, San Francisco.

National Research Council. 1999. New strategies for America's watersheds. Committee on Watershed Management, Water Science and Technology Board, Commission on Geosciences, environment, and resources. Washington, DC. 311pp.

Whiteman, C. D. 2000. Mountain meteorology. Oxford University Press. 355pp.

U.S. Environmental Protection Agency. 1994. The statewide watershed management course. Office of Water. Washington, D.C.

Web Based References:
All links were accessed January 2002. University or class notes may change over time, government links are usually forwarded.

USDA Agricultural Research Service. 2002. Revised Universal Soil Loss Equation. http://www.sedlab.olemiss.edu/Rusle.

USDA Natural Resources Conservation Service. 2002. National Water and Climate Center. Hydraulics and Hydrology Section. http://www.wcc.nrcs.usda.gov/water/quality/hydro/Information_References/information.

USDA Natural Resources Conservation Service. 2002. National Water and Climate Center. National Engineering Handbook. Includes a glossary. http://www.wcc.nrcs.usda.gov/water/quality/common/neh630/4content.html

Slides used in lecture

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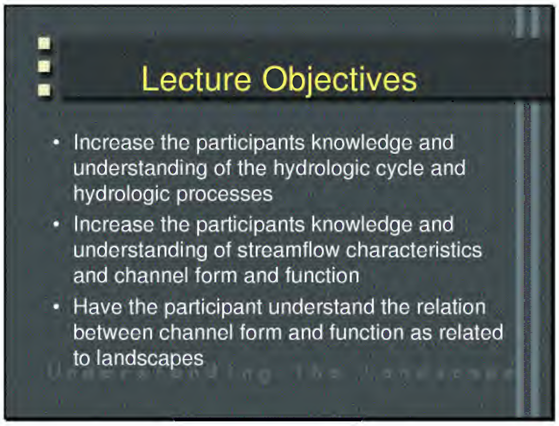

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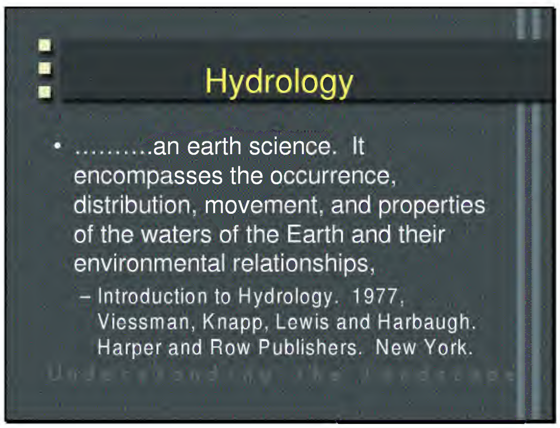

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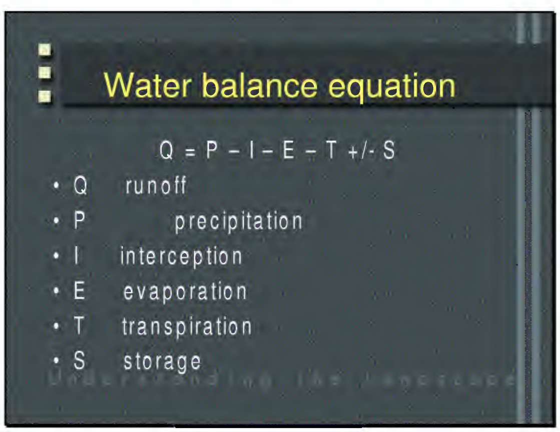

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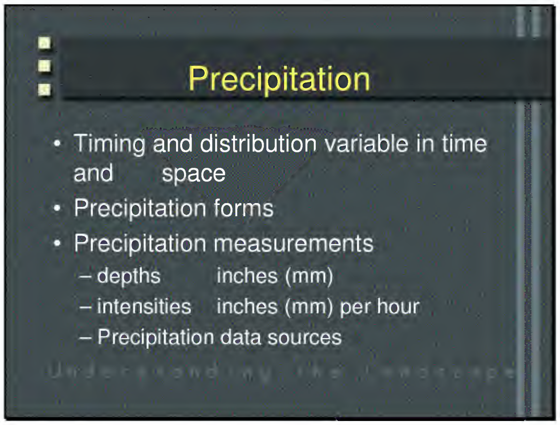

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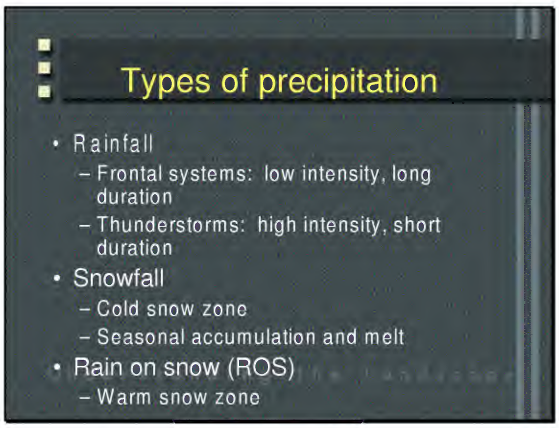

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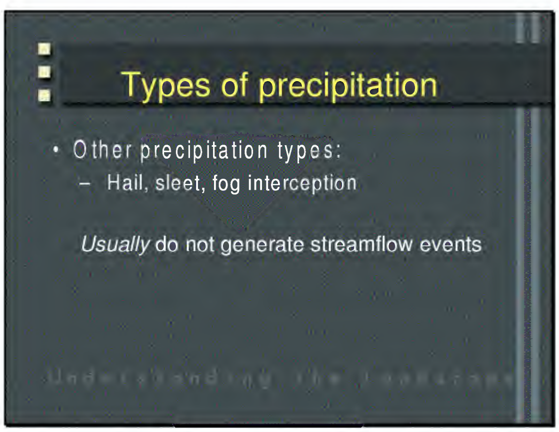

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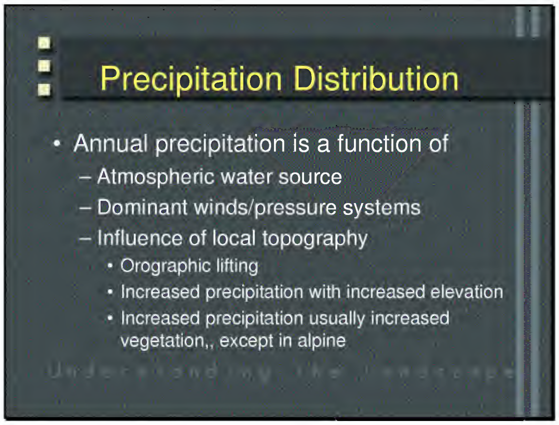

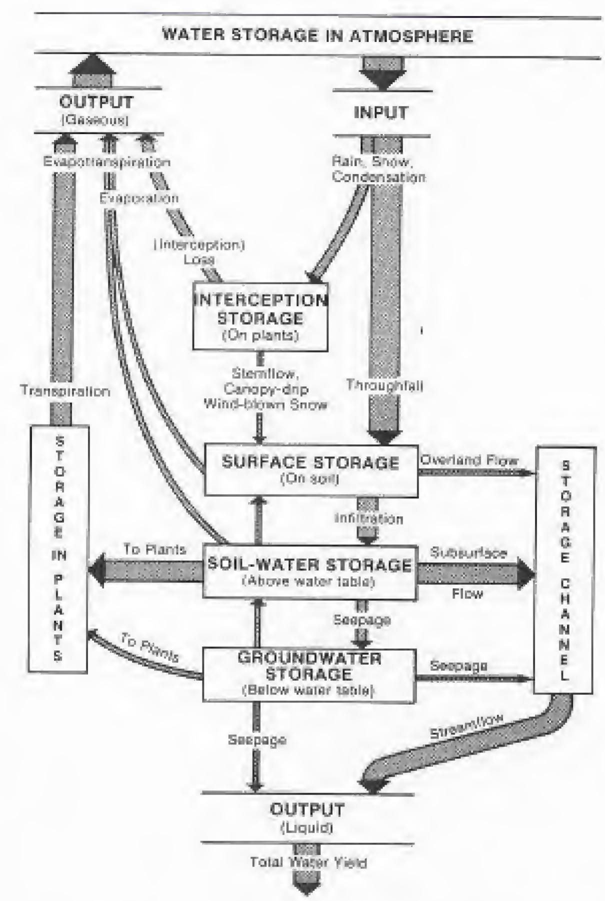

Figure III.1—The hydrologic cycle consists of a system of water storage compartments and the solid, liquid, or gaseous flows of water within and between the storage points (Anderson and others 1976).

Figure referred to in lecture
(not displayed in video)

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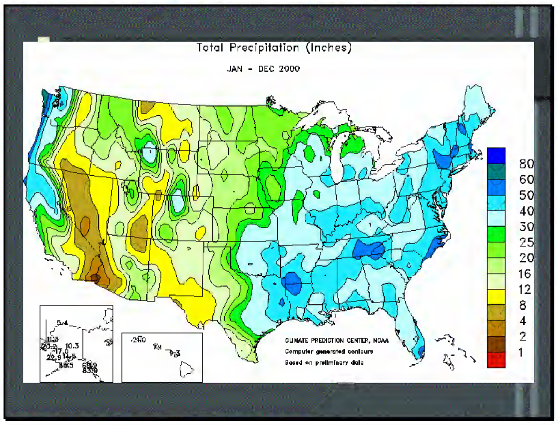

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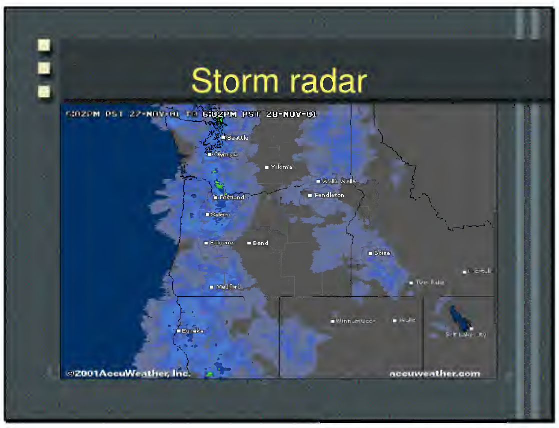

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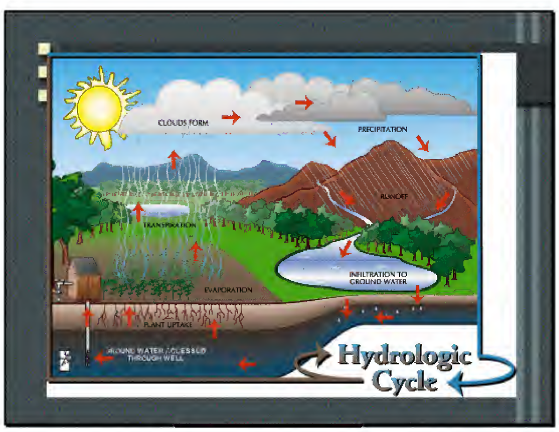

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Interception

- Effects of vegetative cover
  - overstory
  - understory
  - litter
  - surface roughness

Slide 12

Evaporation and Transpiration

- Precipitation losses
- Interception/evaporation
- Sublimation
- Transpiration
- Evapotranspiration temperature dependent

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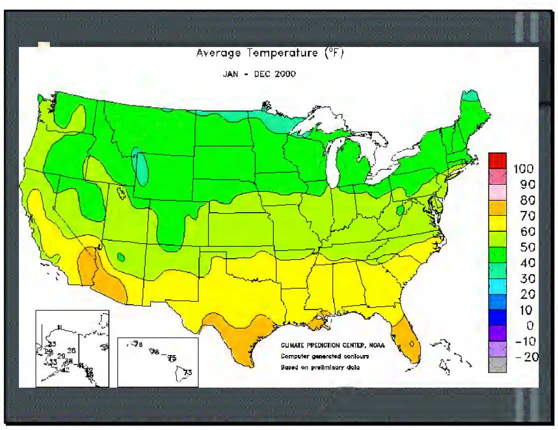

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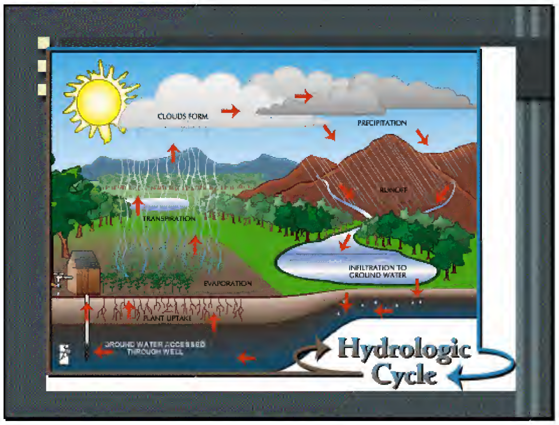

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Infiltration

- Passage of water through the air-soil interface
- Movement of water into the soil to become soil water and/or streamflow
- Measured as inches (mm) per hour
  - Depth of water entering soil over a period of time

Understanding the Landscape

Slide 16

Infiltration

- Infiltration rates generally decrease over time
- Soil moisture
- Soil texture and organic matter
- Soil pores wetted
- Wetting of soil OM and colloids

Understanding the Landscape

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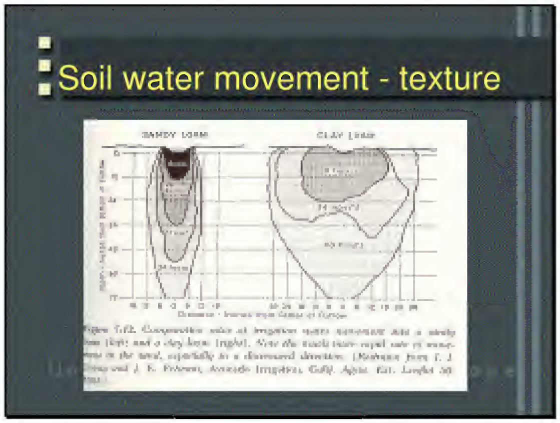

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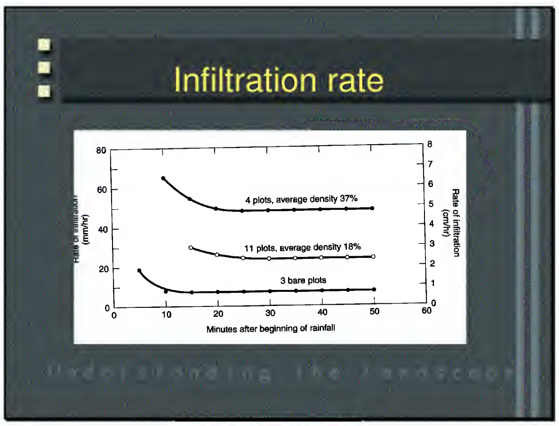

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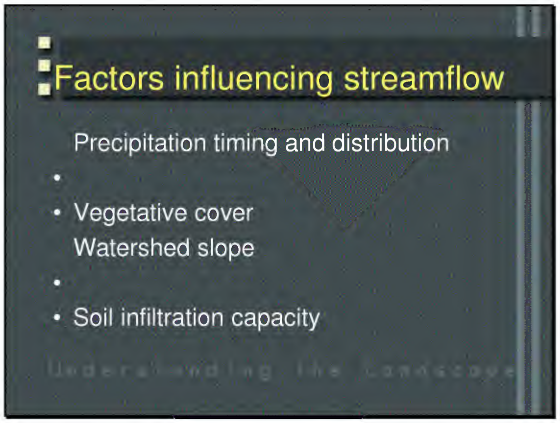

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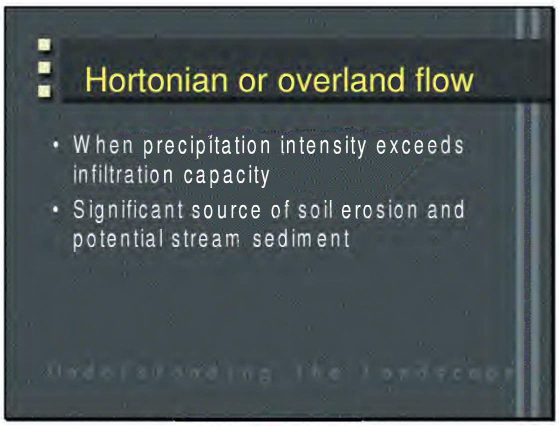

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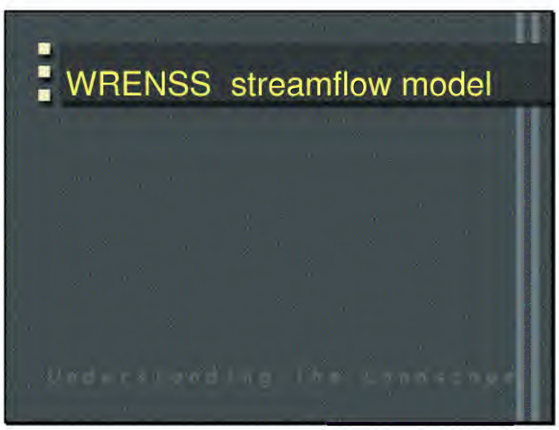

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Discharge calculation

- Discharge denoted as Q
- Q = W x D x V
- W width D depth V velocity
- Cubic feet per sec
- Water year begins October 1

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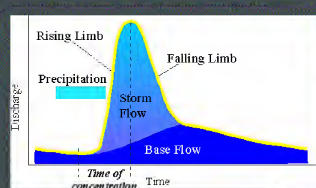

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Stream gauging

- Natural control of stream
- Measure velocity and area to calculate Q
- Often measure stage
- Elevation (or depth) of water above a set datum

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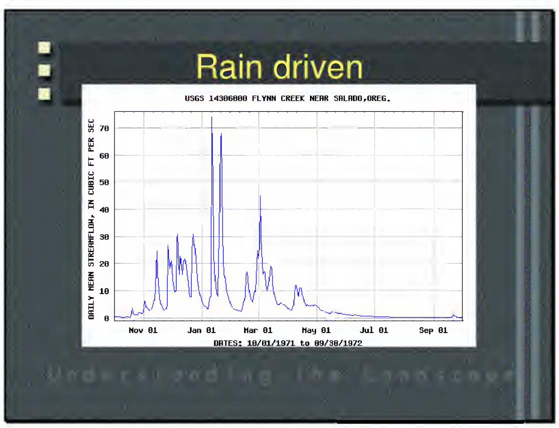

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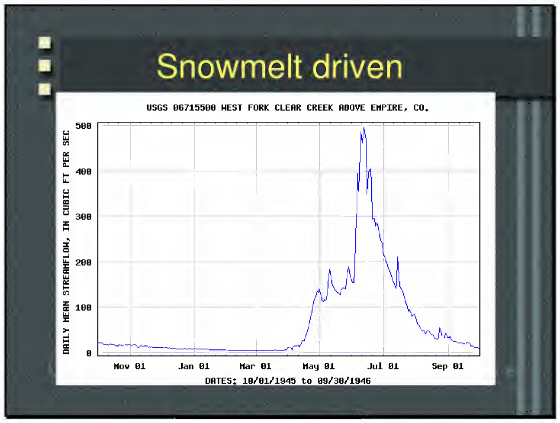

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Streamflow data

- Many stream gauging programs include real time data
- Historical records are available through the USGS web site
- Many states have similar programs

Understanding the Landscape

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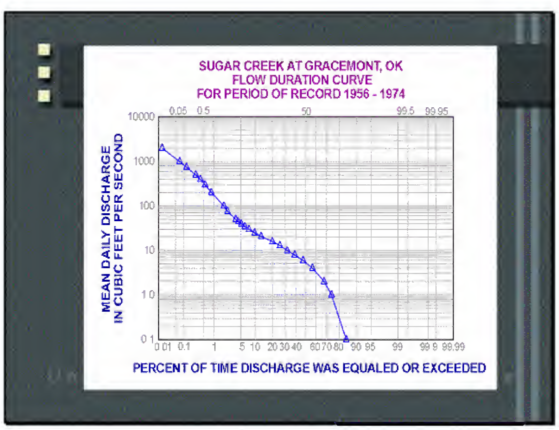

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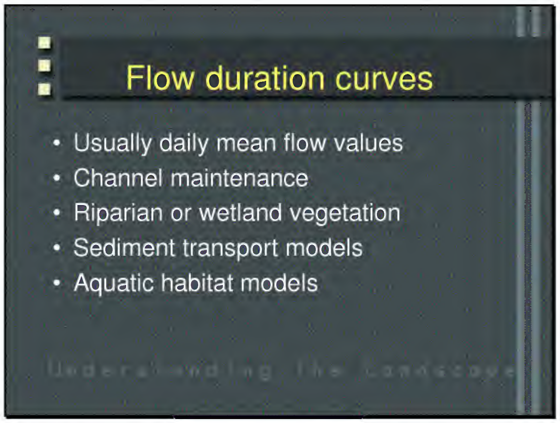

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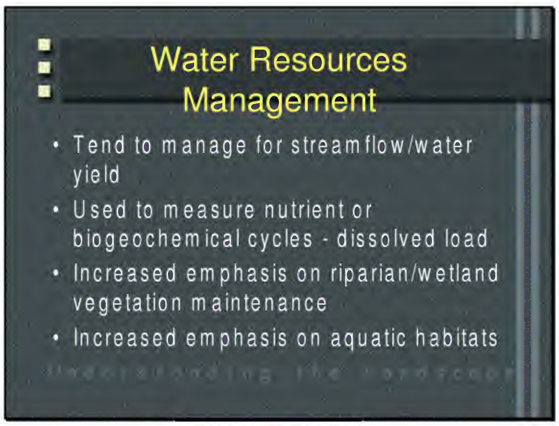

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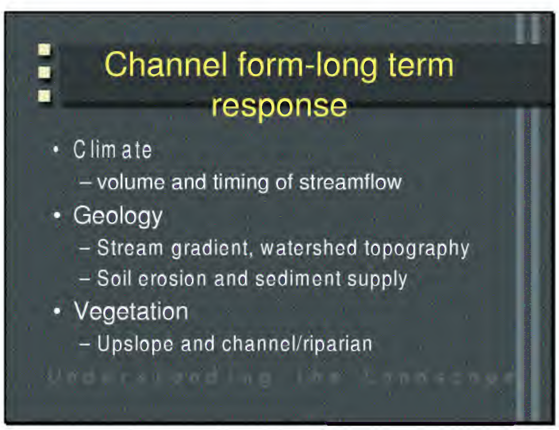

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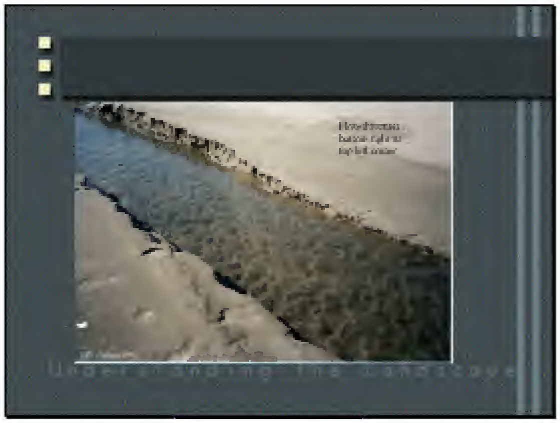

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Channel form short term response

- Soil erosion USLE or RUSLE
- Delivery of eroded materials to stream or in-channel erosion produces sediment
- Sediment movement often episodic
- In-channel storage
- Sediment definition function of particle size and transport mechanisms

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Sediment movement

- Suspended sediment
  - Turbidity as surrogate measurement
  - Usual state water quality standard
- Saltation load
  - Larger sediment sizes partially suspended and bounces along stream bottom
- Bedload
  - Larger particles move along stream bottom

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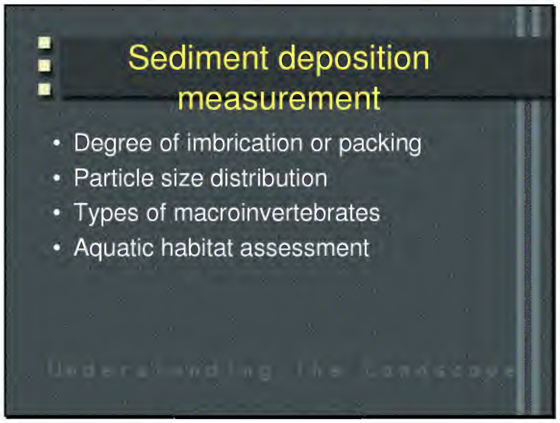

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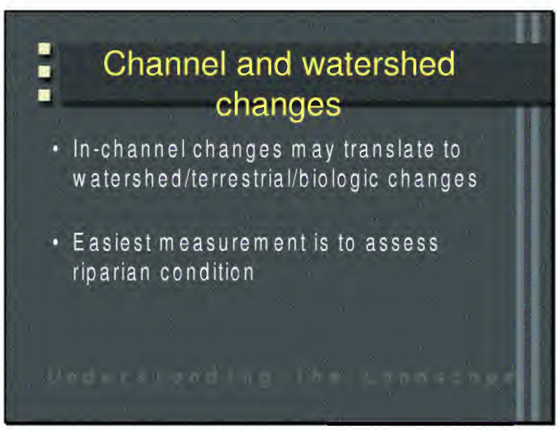

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Riparian

- Transitional zone between aquatic and terrestrial ecotypes
- Vegetation indicative of saturated/ wet soils
- Possibly hydric soils
- Water table at or near the soil surface
- Diagnostic criteria for wetlands

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Riparian Assessment

- Proper Functioning Condition (PFC)
- Check off list
  - Hydrology and stream channel
  - Soils
  - Vegetation
  - Upstream influences

Understanding the Landscape

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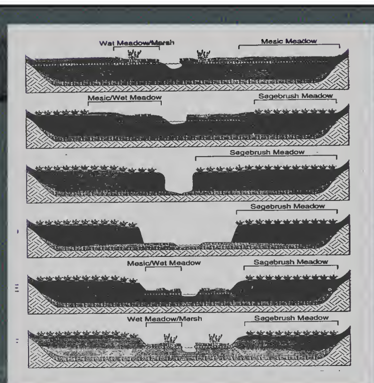

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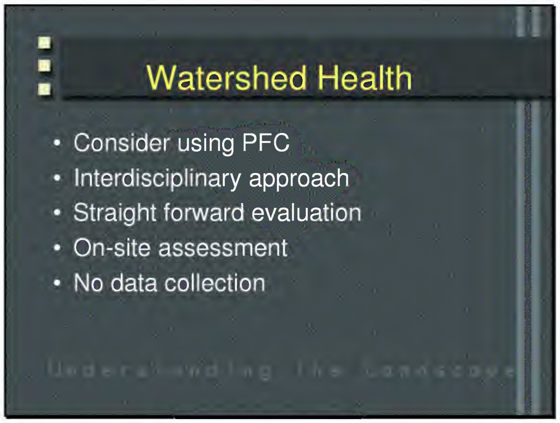

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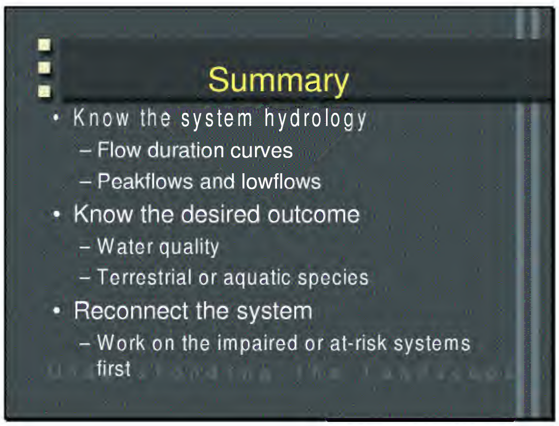

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